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Use of magnetic tracer and radio-cesium methods to determine past cropland soil erosion amounts and rates

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ABSTRACT

The primary objective of this research was to determine the soil erosion rates in cropland of west central Illinois using a magnetic tracer (fly ash) and radio-cesium (cesium-137). The fly ash and cesium-137 accumulation on a stable cropland/hayland summit was determined using a spiral transect. This reference site was used as a baseline and then compared with the fly ash and cesium-137 levels in adjacent cropland landscape positions to estimate loss from erosion. The cesium-137 and fly ash data suggests that cropland lost significant sediment, fly ash and cesium-137 to erosion process especially from the upper and lower backslopes and footslope. The amount and rate of erosion predicted for each cropland landscape position using the fly ash and cesium-137 methods were determine for the 1910 to 1960, 1960 to 2009 and for the entire 100-year time periods. The fly ash and cesium-137 determined erosion amounts and annual soil erosion rate for cropland landscapes positions were highest for the upper and lower backslopes. Past backslope annual erosion rates for three different time periods were 51 Mt ha^{-1} yr^{-1} or less and above the tolerable soil loss rate of 11 Mt ha^{-1} yr^{-1} for Hickory soils. However, the predicted fly ash annual erosion rates for the last for the last 50 years using cesium-137 deposition was higher than annual erosion rates for the 1910 to 1960 time period using the difference between the two methods. The reason for the higher erosion rates for the 50 years after 1960 than before was most likely the continued use of moldboard plowing, up and down the slope plowing and the more intensive corn–soybean rotation without forages and small grains. These methods provide a way to document past cropland soil erosion amount and rates for three different time periods (1910 to 1960, 1960 to 2009 and 1910 to 2009).

1. Introduction

Fly ash is particulate matter resulting from high temperature combustion of coal. It is produced in a variety of boilers, including those in steam locomotives and steam-powered farm machinery. Until recent technologies allowed removal of fly ash from stack gases emanating from boilers, the ash was a component of smoke and was deposited over a wide area around the sources, especially near coal-fired power plants. The principal minerals in the coal of the central USA are feldspars, pyrite, siderite, quartz, calcite, and clay minerals, mostly kaolinite (Harvey and Ruch, 1986). The minerals are vitrified above ~1473 K, and a common product is spheres composed of glass, quartz, mullite, wustite, and magnetite (Huffman and Huggins, 1986). Recently, sphere occurrence and abundance have been used to identify sediments laid down during the industrial epoch (Locke and Bertine, 1986). The occurrence of ferrimagnetic minerals, usually embedded in the glassy phase, offers a convenient way to separate the spheres for identification and analysis.

The use of fly ash and magnetics provides a time marker extending back to at least the 1850s, which, in central Illinois, coincides with railroad development and initial period of American cultivation. Fly ash related to steam locomotive use in the state was widespread, inasmuch as installed track increased from initial construction in the 1850s to 16,000 km in the 1920s. Some fly ash may be derived from steam-powered farm equipment. Threshers and self-propelled tractors, the latter coming into greatest use from 1880 to about 1920 (Wik, 1953), would produce magnetic fly ash, their boilers being fed by soft (bituminous) coal. For economic and supply reasons, however, many steam boilers on farms were fired with straw or wood which probably did not produced highly siliceous, glass-phase fly ash.

The fly ash present in soils can be used to identify sediments accumulated since Euro-American settlement and to interpret the stratigraphy of sediments and their relationships to the underlying soils. Jones and Olson (1990) found that fly-ash spheres were present in

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